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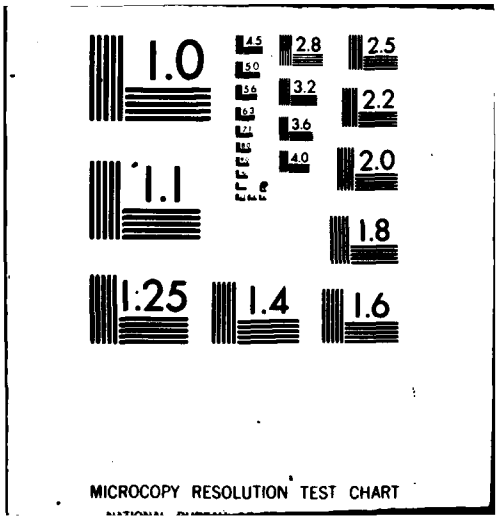
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Institute's activities have been concerned with evaluating the influence of various stressors, physiological and psychological, on man's ability to adapt. Two recent projects reflect these research activities. Utilizing exercise as a stressor, we have conducted studies which were designed to (a) determine the capability of women to perform sustained submaximal work and (b) to determine the effects of prior exercise on sleep patterns as

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exemplified by changes in types of sleep and associated cardiovascular parameters. Women (maximum aerobic capacities of 41 to 65 $ml \cdot kg \cdot m^{-1}$) walked at four different percentages of their max values for periods of up to 8 hours at 30%, 7.2 hours at 50%, 4.1 hours at 65%, and 1.7 hours at 75%. The metabolic, endocrine, and cardiovascular responses will be presented. A second study (men and women subjects) evaluated sleep patterns following a period of exhausting submaximal exercise. Subjects slept the first night to be adapted to the procedures; EEG recordings and cardiac outputs were measured on the next three nights. The first night was a control sleep, the second occurred after an exercise bout, and the final night was considered to be a recovery night. The exercise intervention evoked marked effects on the quantity and temporal distribution of slow-wave sleep (stages 3 and 4) and the time to onset of REM sleep. Cardiovascular responses were also altered although the basic rhythmic decrease in control cardiac output (to 50%) was maintained. The results suggest that prior exhaustive exercise effects sleep primarily in the early portion of the night. The potential effect of these disturbances on other performance measures may be significant. Other studies underway or completed are discussed in greater detail.

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PHYSIOLOGICAL PERFORMANCE RELATED TO MULTIPLE STRESSES SUCH AS THOSE EXPERIENCED IN AIR FORCE OPERATIONS

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INTERIM REPORT
ON AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
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(January 1981 through December 1981)

The attached listing of research published, accepted for publication, and submitted represents our continued interest in the physiological and psychological responses of man to stressors. Two extensive reviews have also been completed. In these reviews, we consider (a) the impact of additional metabolic input on man's ability to perform in a cold environment, and (b) the ability of man to transfer oxygen to his tissues. The exercise and cold manuscript delineates the factors that modify thermoregulatory and circulatory adjustments as a result of exposure to low ambient temperatures as well as the significance of the development of a hypothermic state on man's performance and survival. We bring into perspective the incidence of hypothermic deaths as related to rest and work in low ambient conditions as they are influenced by the aging process. The second review considers the effects of variables such as exercise, disease, and exposure to altered oxygen levels on the transport of oxygen to active cells.

We have made additional investigations on exercise performance. One such study was concerned with the need for and the potential benefits of a preliminary warm-up on work performance. We concluded that although warm-up might be useful for tasks in which the initial work loads are maximal or supramaximal, it is of questionable value in endurance tasks which begin at a high but submaximal intensity. We were also concerned with the question of the efficiency at which work is performed when someone else determines the pace at which work is performed. Our first study on this has been published. We also evaluated changes in the electrocardiogram of individuals who performed high-intensity respiratory strains such as would occur in situations where individuals fix their thoracic cage. We found a high incidence of "wandering pacemaker." An extensive review on the physiological changes occurring in man exercising in a cold environment has been accepted and will appear shortly and should prove valuable to the Air Force in determining the potential impact on man operating under cold conditions.

Additional studies on psychological aspects of stress have been completed. Exposure to carbon monoxide at levels postulated to occur in helicopters and in other situations had minimal effects on vigilance. However, such exposure (5% HbCO) significantly decreased the subjects' confidence concerning their performance on the vigilance task. Other reports were concerned with perception of stress - developing a conceptual model of man's responses to environmental stress. The impact of an increased cardiac output and elevated heart rate in what may be considered minor levels of stress was evaluated. It was clearly identified to be associated with psychological parameters and not related to metabolic factors.

We have been emphasizing two major programs, and the present state of our observations is briefly summarized. Since these are on-going efforts, we have no final conclusions to report. We initiated long-term studies on women working at various levels of their maximal aerobic power. The maximal aerobic power ($\dot{V}_{O2\ max}$) of our present subjects ranged from 41 to 65 ml·kg·min^{-1} (M = 50 ml). This represents a wide range of women's capacities. Young women worked at various intensities in a schedule that required consecutive 50 minutes of work and 10 minutes of rest. Table 1 presents the simplest data, i.e. work time to exhaustion.

TABLE 1. RELATIVE WORK LOADS

30% max	=	8 hours completed easily by all subjects.
50% max	=	4 subjects completed 8 hours and 1 subject only 4 hours.
65% max	=	1 subject 8 hours; others much less, their max time being 2 hours 35 minutes.
75% max	=	duration varied from 26 to 141 minutes. The longest duration was accomplished by the subject who was able to complete 8 hours at 65%.

It is quite evident that women perform as well as, if not slightly better than, the men we had studied some years previously. It was somewhat surprising that the women with the highest capacity did not perform at the highest level during the submaximal efforts. We are in the process of analyzing various hormones and metabolites (as well as circulatory, metabolic, and thermal parameters). This program will continue into the next year, and we anticipate having a complete metabolic, cardiovascular, and hormonal profile on women engaged in prolonged work.

Our second major project was concerned with the effects of two types of exhaustive exercise on nocturnal sleep and cardiovascular functions. Subjects performed (a) maximal work which can be completed in 20-25 minutes, and (b) submaximal (50-75% of maximal effort) work of 3-4 hours duration. Each subject sleeps four nights - an adaptation night (just instruments and information recorded but not used), a baseline night, an exercise night, and a recovery night. This regime requires a total of eight nights for each subject.

We have completed evaluating the effects on nocturnal sleep patterns of an acute bout of high-intensity exercise (50-75% of $\dot{V}_{O2\ max}$), carried to the point of volitional exhaustion. Five female and four male subjects participated for four consecutive nights, with exhaustive exercise performed on the afternoon of day 3. Subjects were moderately active and moderately fit (mean $\dot{V}_{O2\ max}$ = 46.8 ml/kg).

The exercise intervention evoked marked effects on the quantity and temporal distribution of SWS (stages 3 + 4). SWS prior to the first REM period increased from a mean of 31.3 minutes to 47.4 minutes. Stage 4 sleep increased, as did total SWS. Latency to stage 4 decreased as well. Coupled with the enhanced accumulation of SWS early in the night was a significant increase in latency to first REM onset, a decrease in the length of the first REM period, and a decrease in the length of the first REM cycle. The increases in SWS were largely at the expense of total REM sleep, which decreased significantly after exercise. All of these sleep variables returned to baseline levels on the recovery night after exercise.

The magnitude of the increase of SWS prior to the first REM period was sex-related, with this increase averaging +24.0 minutes for women and, for men, +5.7 minutes ($t_7 = 5.76$, $P < 0.001$). Moreover, for women a correlation of 0.85 ($P < 0.05$) was observed between this increase and total caloric expenditure (expressed as kcal/kg). In contrast, no apparent correlation was observed in men.

The results suggest that exhaustive exercise affects sleep primarily in the early portion of the night, inducing an increase in SWS "pressure" at the expense of REM sleep. Changes in the duration of SWS prior to REM onset may be the most sensitive indicator of exercise effects on sleep, since this change relates most strongly to total energy expenditure. The sex differences in response to exercise were unexpected but did not seem to be related to differences in exercise performance, fitness, or habitual activity levels.

Impedance cardiography was used to provide measures of heart rate, stroke volume, and cardiac output. These variables were sampled at "lights out" (baseline), sleep onset, and each half hour throughout the night. On the exercise night, heart rate was initially elevated over baseline nights, and remained elevated throughout the whole night. An elevated cardiac output was observed in the early portion of the night, due primarily to the increase in heart rate. These observations are of considerable significance, since on non-exercise nights cardiac output reaches a low point (approximately 40-50% reduction) at 0300 to 0500 hours. The higher levels observed during exercise nights were unexpected and suggest that an increased cardiovascular load may interfere with successful recovery.

We have continued with our investigations into plasma shifts under a variety of conditions. We have shown that exercise in a hypoxic environment, despite the theoretical suggestions that such exposure could alter the permeability of the vessels, did not in fact alter the movement of plasma out of the circulation. We showed that the maximum amount of fluid shift, even when subjects are engaged in supramaximal work, does not exceed some 20-22%. This confirms our previous work conducted in hot environments. The significance of this limitation on plasma movement is unknown

at this time. We have underway plasma volume shift studies concerned with aging (oldest subjects 74 years) and diabetes. In the latter condition, we postulated that increased capillary permeability consequent to the disease would result in more rapid and even greater losses of plasma. Additional studies involve evaluation of shifts in cool to cold environments. It is known that there is a 10-15% hemoconcentration in such conditions, but the factors responsible for such are unknown, as are its effects on the circulatory and thermo-regulatory systems.

We have also developed new and most comprehensive computer systems to evaluate cardiovascular function. This includes two different uses of computer interaction based on a real-time analysis of events. In the first unit, we have utilized a new display unit (Genisco) which not only records (in multiple color outputs) all circulatory parameters measured but simultaneously calculates a variety of derivative functions. At one-minute intervals, trend plots of the accumulated direct and derived data are displayed. At the conclusion of the experiment, hard copies are immediately available. All data can be checked again at this time and are reviewed for completeness, providing information not available in any other known system. Our second system is an independent microprocessor unit which was designed to obtain circulatory data (and eventually, in combination with another microprocessor being developed, will have all metabolic data also on-line) during exercise. It is postulated that this system can be eventually developed so that performance capability of man can be determined easily under field conditions.

It is apparent that we have been most productive not only in the general area of stress responses but in the area relating work performance to the overall physiological and psychological responses and adaptations occurring under a variety of additional stresses. All of our research is based on the concept that man is subjected to multiple stresses and his adjustments to such should be the basis of studies on man under stress.

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